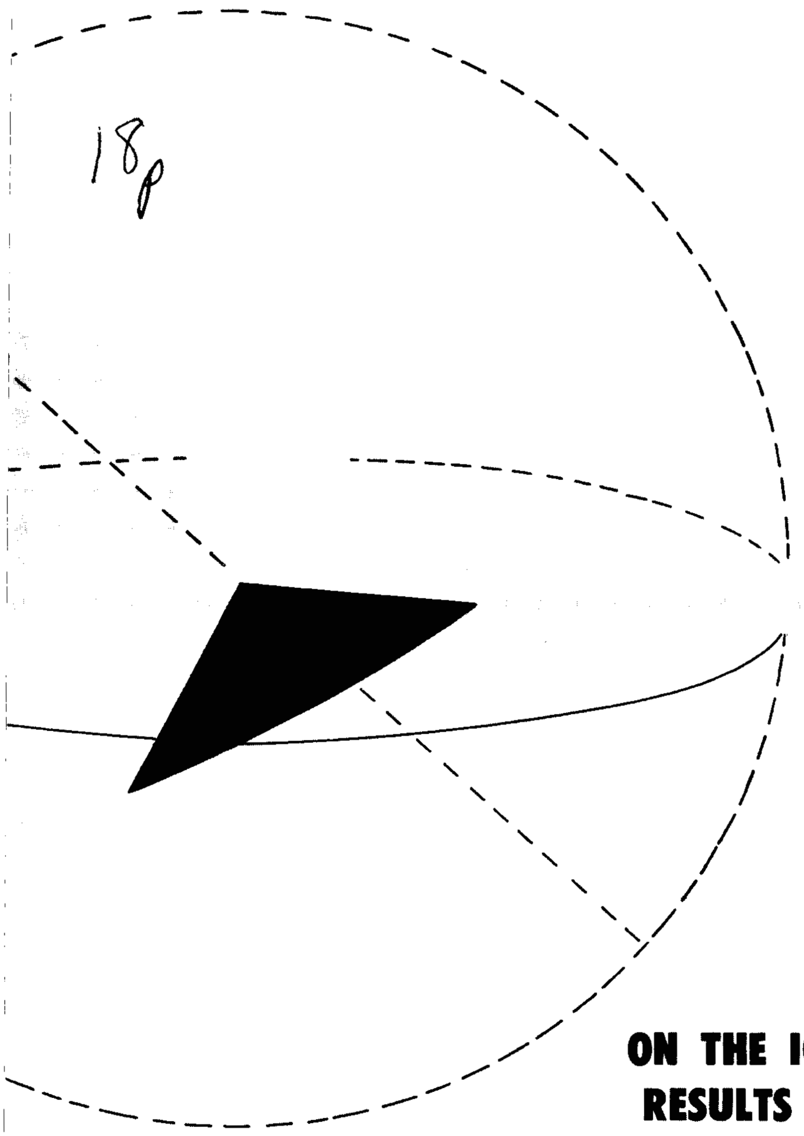

ON THE IONOSPHERIC INTERPRETATION OF THE RESULTS OF RADIO OBSERVATIONS OF VENUS

Part I

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Part 1[1]

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The ionosphere model appears to hold the greatest promise for the explanation of the data obtained by radio observations of Venus. This paper considers the primary difficulties associated with this hypothesis and the possible techniques for overcoming these difficulties. The very high concentration of electrons in the Venus atmosphere, which is required to account for the radio observational data, may, in fact, exist if (1) radiative recombination is the recombining mechanism and (2) the same ionizing agent acts in the night ionosphere of Venus as acts in the night ionosphere of the Earth.

Agreement of the ionospheric hypothesis with data resulting from radar studies of Venus can be obtained if the radiation with $c\lambda$ = 70 cm is reflected from the maximum of the electron concentration in the ionosphere while the radiation with $c\lambda$ = 10 and 40 cm is reflected from the surface of the planet. The high temperature of the radio-frequency radiation of Venus in the centimeter band is explained by the high electron temperature of the ionosphere; the absence of an increase in temperature for the 20-cm band is explained by the presence of an upper layer of lower temperature above the layer with the high electron temperature. Author

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At the present time there is extensive discussion (Ref. 1 – 6) of the question of the interpretation of the high temperatures obtained during the study of the radio-frequency radiation of Venus in the centimeter and millimeter bands. According to Mayer and others (Ref. 7, 8), the measurements carried out at the 3- and 10-cm wavelengths gave a radio-brightness temperature of Venus of the order of 600°K. The American investigators (Ref. 9, 10) obtained a temperature of the order of 300 – 400°K at the millimeter wavelengths. According to the data of Salomonovich and Kuz'min (Ref. 11 – 13), the temperature in the millimeter band is 370 – 390°K, while, at the 9.6-cm wavelength, the mean temperature is about 690°K.

There are several hypotheses for the explanation of the high temperatures obtained in the centimeter band and, also, of the temperature differences at the various wavelengths noted above.

One of the hypotheses (Ref. 1, 14) assumes that the high temperature obtained in the centimeter band applies directly to the surface of Venus, while the lower temperature of the microwave radiation is explained by the absorption of this radiation in the colder layers of the Venus atmosphere. However, the explanation for such a high temperature of the planet's surface meets with serious difficulties. Since, in the absence of an atmosphere the surface temperature of Venus should be of the order of 250°K (Ref. 15), it is necessary to postulate the presence of a strong "greenhouse effect" in the lower layer of the planet's atmosphere. In order that the greenhouse effect might create a sufficiently high temperature, according to Barrett (Ref. 3), it is necessary to assume a pressure of 10 atm on the surface of Venus and a water content of over 3% in the atmosphere. These conditions diverge quite a bit from those presently accepted for the atmosphere of Venus (*e.g.* Ref. 16, 17).

Opik (Ref. 2) suggested that continuous strong dust storms in the lower layers of the atmosphere of Venus might serve as a possible mechanism for causing the heating of the surface to the high temperatures noted. However, this hypothesis also encounters numerous difficulties (Ref. 18).

Tolbert and Straiton (Ref. 5) proposed the hypothesis that the supercharging of drops in clouds similar to the rain clouds in the Earth's atmosphere may be responsible for the Venus radio-frequency radiation. However, the essential difficulty of this hypothesis lies in the necessity that the clouds consist of matter with a crystalline structure rather than of water.

Jones (Ref. 4) suggested that the high radiation temperature of Venus in the centimeter band might be due to the ionosphere of the planet, which, at the same time, is sufficiently transparent so that the radiation in the millimeter band, coming from the considerably colder surface, is able to pass freely through it.

Similar ideas have been expressed by Salomonovich and Kuz'min (Ref. 11). However, this hypothesis postulates the existence on Venus of a dense atmosphere with a concentration of electrons exceeding that in the Earth's ionosphere by a factor of $10^2 - 10^3$.

Thus, all the hypotheses for the explanation of the high temperatures obtained at the centimeter wavelengths encounter considerable difficulties. On the other hand, the necessity for the interpretation of the available data is obvious, and this question is a very urgent one at the present time.

It appears that the ionosphere hypothesis is the most promising for the interpretation of the data from the radio observations of Venus. The dynamics and thermodynamics of the lower layers of the Earth's atmosphere have received thorough study, and no real surprises are expected in this area. However, the study of the ionosphere only really began with the inception of rocket technology. The previous concepts of the morphology of the Earth's ionosphere and of the physical and chemical processes taking place in it, obtained by the use of only Earth-surface observations, had to be reconsidered in their entirety (Ref. 19 – 21). As a result, data which had been in conflict with the "classical" concept were found to have simple and natural explanations in the light of the new information.

The primary task of the present investigation is to consider the difficulties arising in the attempt to apply the ionosphere hypothesis to the explanation of the results of the radio-frequency observations of Venus and to consider the possible means for overcoming these difficulties. We did not set ourselves the task of creating the most probable, from the point of view of the actual physical conditions, ionosphere model (this was done in Ref. 22); rather, we have considered only the question of the conditions under which the experimental data can be explained by the existence of an ionosphere (if they can be).

1. First of all it is necessary to establish in principle the possibility of the existence of electron concentrations in the Venus atmosphere exceeding that in the Earth's atmosphere by two or three orders of magnitude. From the elementary theory it is known that the concentration of electrons in the ionosphere is proportional to the square root of the flux of the ionizing radiation and inversely proportional to the square root of the electron recombination coefficient. If the electron concentrations in the atmospheres of the two planets differ by two orders of magnitude, this means that either the intensities of the ionizing radiation or the electron recombination coefficients will differ by four orders of magnitude.

The intensity of the solar ionizing ultraviolet radiation for two neighboring planets of the solar system cannot differ strongly. The solar radiation flux on Venus is approximately twice as large as that on

Earth. The intensity of the corpuscular flux is strongly dependent on the magnitude of the magnetic field of the planet and on other factors; but, here again, it is not realistic to assume a difference of four orders of magnitude. It is apparent that the solution of the problem must be looked for in the magnitude of the electron recombination coefficient.

The recombination of ions with electrons can take place in two ways: (1) the molecular ions recombine in accordance with the dissociative recombination reaction

$$XY^{+} + e \rightarrow X + Y$$

having a rate coefficient of $10^{-6} - 10^{-7}$ cm^3 sec^{-1} (Ref. 21); (2) the atomic ions recombine in accordance with the radiative recombination reaction

$$\mathrm{A}^{+} + e \rightarrow \mathrm{A} + h\nu$$

having a rate coefficient of the order of 10^{-12} cm^3 sec^{-1} (Ref. 23). Thus, the rate coefficients of these reactions differ by 5–6 orders of magnitude. Therefore, for a comparable intensity of the ionizing radiation, the difference in the electron concentration for the different planets could reach three orders of magnitude as a result of the difference in the effective recombination coefficients.

The question of the magnitude of the electron recombination coefficient in the Earth's atmosphere is presently receiving considerable discussion (Ref. 21). Experimental data obtained with the aid of rockets and artificial satellites (Ref. 24–27) indicate the presence of large quantities of molecular ions in the Earth's ionosphere. Theoretical calculations (Ref. 28–30) made on the basis of these data indicate that the primary process in the disappearance of ions is dissociative recombination. The atomic ions give up their charge to the molecules as a result of the ion-exchange reactions while the molecular ions formed lose their charge on recombining with the electron (Ref. 30). This conclusion is confirmed by a comparison of the vertical profile of the concentrations of the atomic and the molecular ions (Ref. 31).

At present, there are no experimental data on the ionosphere of Venus. In the study of Ref. 2, a model of the Venus ionosphere was constructed on the basis of the consideration of the recombination and ionization processes as being similar to the processes in the Earth's atmosphere. Here it was assumed that the Venus atmosphere consists of CO_2 at all heights. In this case, the atmosphere of Venus contains molecular ions CO_2^+ and CO^+ (Ref. 22) up to very high altitudes, and the effective electron recombination coefficient is determined by the dissociative recombination processes. However, it is necessary to consider the formation of the ionosphere under conditions in which the ion-exchange processes and dissociative recombination do not play a significant role. Such a situation might arise if, beginning with a certain altitude, the atmosphere of Venus consists, as a result of dissociation, of only neutral atoms and atomic ions.

There is the second possibility that the reaction of the transformation of the atomic ions into molecular ions by means of the ion exchange with the CO_2 molecules may not take place as efficiently as is assumed in Ref. 22 by analogy with the Earth's ionosphere. In both of the cases considered, the effective recombination coefficient α' in the ionosphere of Venus will be determined by the radiative recombination processes and will be of the order of 10^{-12} cm^3 sec^{-1}. It should be noted that in the work of Jones (Ref. 4) mentioned previously, this very value of α' was used, although without any justification. As mentioned above, the reduction of the magnitude of the effective recombination coefficient by $5-6$ orders of magnitude corresponds to an increase in the equilibrium electron concentration by $2-3$ orders, and, therefore, for $\alpha' = 10^{-12}$ cm^3 sec^{-1}, the electron concentrations in the atmospheres of Venus and the Earth must differ by two to three orders of magnitude.

2. All the available radio observation data relate to the night side of Venus. Therefore, it is necessary to establish the possibility of the existence of high electron concentrations in the night Venus atmosphere, keeping in mind that Venus days may be much longer than Earth days.

Let us consider the night ionosphere of the Earth. In Ref. 32, it is shown that the existence of the night ionization at the altitudes of the F layer and, also, the existence of the ionosphere during the polar night cannot be explained without the hypothesis of the presence in the Earth's ionosphere of an ionizing agent other than the solar radiation which acts at night. According to the calculations presented in Ref. 32, fluxes of soft electrons are responsible for the ionization at the altitudes of the F layer at night. These calculations resulted in a number of recombinations in the column of the night ionosphere equal to $2 \cdot 10^{10} - 2 \cdot 10^{11}$ recombinations/cm^2 sec. However, in the calculation of this quantity, use was made of the daytime values for the electron recombination coefficient α' taken in accordance with Ref. 33. Since the magnitude of this coefficient increases at night (Ref. 19) as a result of the experimentally determined increase in the proportion of the molecular ions, this estimate should be re-evaluated. Calculations carried out with consideration for the night-time increase in the effective recombination coefficient give a number of recombinations in the column of the Earth's atmosphere equal to $10^{11} - 10^{12}$ recombinations/cm^2 sec. Two possible values are given, just as in Ref. 32, since there is an uncertainty in the value of the magnitude of the dissociative recombination reaction coefficient which determines the quantity α'.

As indicated above, the coefficient α' in the Venus atmosphere can be of the order of 10^{-12} cm^3 sec^{-1}. Using this value, the magnitude of the integral $\int n_e^2\, dz$, estimated on the basis of the radio data, is $3 \cdot 10^{24} - 10^{25}$ cm^{-5} (Ref. 4, 11), which leads to a total number of recombinations in the column of the Venus atmosphere equal to $3 \cdot 10^{12} - 10^{13}$ recombinations/cm^2 sec. Thus, the value of the integral $\int \alpha' n_e^2\, dz$ required for the interpretation of the radio observations is acceptable if it is assumed that the same agent acts in the night Venus atmosphere as acts in the atmosphere of the Earth. In order to explain a certain disparity of the indicated magnitude of $\int \alpha' n_e^2\, dz$ obtained for the Earth and that necessary for Venus, it must be assumed that the flux of this agent in the Venus atmosphere is several times greater than in the Earth atmosphere. This assumption is fully acceptable since the electron fluxes may be strongly dependent, *e.g.*, on the magnitude of the magnetic field of the planet. Jones (Ref. 4), for example, considers as a possible agent for the creation of the ionosphere of Venus, fluxes of protons which might be sufficiently effective in the planet's atmosphere if its magnetic field amounts to about 1/30 of Earth's. The question of the magnitude of the magnetic field of Venus has been considered theoretically in Ref. 34, 35, where it is shown that the magnetic field of Venus must be significantly weaker than the magnetic field of the Earth. Preliminary data obtained by the American space rocket *Mariner 2* also indicate that the magnetic field of Venus is very weak (Ref. 36).

From what we have said it follows that the assumption of the existence of high concentrations of electrons in the night atmosphere of Venus, necessary for the explanation of the radio observational data, may be well founded under certain definite conditions (Ref. 6).

3. Consider the question of the agreement of the concept of the Venus ionosphere as a source of decimeter wavelength radiation with the data from the radar studies of the planet.

If the optical thickness of the ionosphere of Venus is sufficient to give a high brightness temperature of the decimeter radiation, then, when Venus is illuminated with radar energy, the radio waves in the decimeter band should be strongly absorbed in its ionosphere. At the same time, the transparency of the ionosphere should decrease rapidly with an increase in the wavelength. However, experiments on radar illumination of Venus (Ref. 37 – 40) give nearly identical reflection coefficients of about 10 – 15% (Ref. 37) for wavelengths from 10 – 70 cm.

Let us consider in greater detail the question of the absorption of radio waves in the ionosphere of Venus.

According to the ionospheric interpretation of the experimental data (Ref. 8 – 13), the decimeter radio-frequency radiation from a surface with a brightness temperature of 300 – 400°K, on passing through the ionosphere, is transformed into radio-frequency radiation with a temperature of 600 – 800°K. The higher the electron temperature in the ionosphere, the lower the optical thickness required will be for the corresponding increase in the brightness temperature of the radio-frequency radiation.

Figure 1 shows the variation of the optical thickness necessary to increase the radiation temperature from 300 – 800°K (upper curve) and from 400 – 600°K (lower curve) with an increase in the electron temperature of the ionosphere T_e. It may be seen from the graph that, for an ionosphere electron temperature of 4000 – 5000°K, an optical thickness of 0.075 is sufficient for the temperature rise of interest to us. This magnitude of the electron temperature of the Venus atmosphere is not unacceptable. Experimental data (Ref. 41) indicate that at an altitude of 150 – 200 km in the Earth's ionosphere, the electron temperature is significantly higher than the temperature of the neutral atmosphere and reaches 2800°K. According to the calculations of Gurevich and Tsedilina (Ref. 42), the temperature of the electrons in the Earth's ionosphere may rise to 10,000°K and higher in the presence of electrostatic fields with potential of not less than 0.002 mv/m. The existence of electrostatic fields in the Earth's ionosphere has been determined experimentally (Ref. 43).

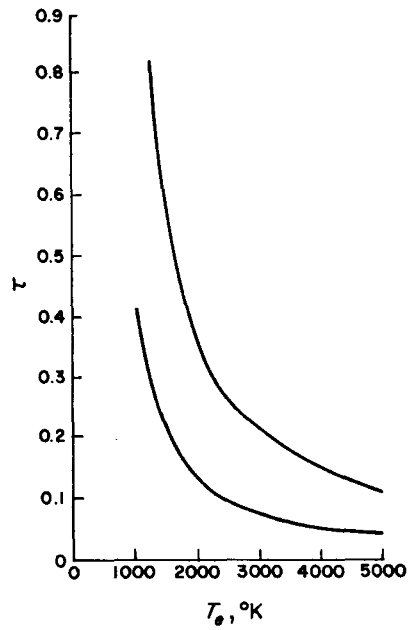

Fig. 1

So, let us assume that for radiation with a wavelength of 10 cm, the optical thickness of the ionosphere is 0.075. In reflecting from the surface, the radio waves pass through the planetary atmosphere twice. With a change in the frequency of the radiation, the optical thickness increases in proportion to the square of the wavelength. The transparency of the ionosphere with doubled optical thickness for the wavelengths used in the radar study is:

λ, cm	10	40	70
Transparency	0.86	0.091	0.00075

Thus, the radio waves with lengths of 10 and 40 cm are able to pass twice through the ionosphere but the 70-cm waves are practically completely absorbed in the second passage. If, however, we assume that these waves are reflected from the ionosphere in the vicinity of the maximum electron concentration, then, for an approximately symmetrical ionosphere layer, their reflection coefficient amounts to about 3%, which is quite close to the experimental value (see above).

For the case of reflection of the 70-cm waves from the ionosphere, the radar illumination at these wavelengths should give a reflection coefficient of the order of 3%. The 40-cm wavelengths give approximately the same coefficient for total reflection from the surface taking into account for the absorption in the ionosphere. As for the 10-cm wavelengths, they are, for all practical purposes, not absorbed in the ionosphere at all. In order to reconcile the ionosphere hypothesis with the experimental results, it is necessary to assume that the surface of Venus, or the cloud layer, absorbs the 10-cm waves much more strongly than the 40-cm waves. This may occur, for example, in the case in which there are nonuniformities with dimensions of the order of 10 cm on the reflecting surface.

4. We assumed above that the radiation with a wavelength of 70 cm is reflected from the ionosphere. In order that this reflection may take place, the maximum electron concentration must be not less than $2 \cdot 3 \cdot 10^9$ cm^{-3}. At the same time, in order to explain the radio observational data using the ionosphere hypothesis, it is necessary to assume that for Venus, $\int n_e^2 \, dz = 10^{25}$ cm^{-5} (see above). (This estimate is practically independent of the assumed temperature of the ionosphere since, with an increase in temperature, the transparency of the ionosphere layer increases.) Consider the conditions under which the indicated quantities can be reconciled.

The question of the maximum electron concentration for a given value of $\int n_e^2 \, dz$ reduces to the question of the altitude distribution of the electrons. Observations on rockets and artificial satellites (Ref. 44) indicate that in the Earth's ionosphere the altitude variation of the electron concentration does not satisfy the theory of the simple Chapman Layer. As shown in Ref. 31, the primary cause of this is the ion-exchange reactions which determine the recombination processes in the Earth's ionosphere. The altitude distribution of the concentration of the molecular ions, which lose their charge by means of direct recombination with electrons, is not in contradiction with the simple layer theory. In addition, for altitudes below the F layer, the non-monochromaticity of the ionizing radiation (Ref. 19) is significant, and this may also lead to deviations of the actual distribution of the ion and electron concentrations from the simple layer theory.

In the case of Venus, the ionosphere hypothesis, as indicated above, is applicable for the interpretation of the radio observations only under the condition that there are no ion-exchange reactions in the planet's ionosphere. In addition, we are considering the night ionosphere, whose ionization is produced primarily by corpuscles which, in the first approximation, may be considered to be monochromatic agents. Therefore, in the case of interest to us, the altitude distribution of the electron concentrations can be considered from the point of view of the simple Chapman Layer.

A simple calculation indicates that if $\int n_e^2 \, dz = 10^{25} \text{ cm}^{-5}$ and the altitude distribution of the electron concentration satisfies the simple layer theory, the maximum concentration of electrons will exceed the quantity $2 \cdot 10^9 \text{ cm}^{-3}$ for a height of the uniform atmosphere H of about 7 km. Sagan (Ref. 1), on the basis of observations, considers that the ionosphere of Venus begins at an altitude of the order of 70 km above the layer clouds. From observations of the occultation of Regulus by Venus, a height of the uniform atmosphere equal to 6.8 km has been obtained (Ref. 45). It is necessary to note that deviation from the conditions assumed in the simple layer theory leads to an increase in the thickness of the ionosphere layer and consequently to a decrease in n_e^{max}. Thus, the reflection of the 70-cm radio waves from the ionosphere of Venus is on the borderline of the admissible conditions.

However, it should be noted that a layer of metal ions (Ref. 46) is observed in the ionosphere of the Earth at altitudes of 100 – 105 km, which is significantly narrower than that corresponding to the Chapman Layer. The possibility that similar thin layers with high electron concentrations may be observed in the ionosphere of Venus has not been eliminated.

5. As we have mentioned, it is necessary to assume that the electron temperature of the ionosphere of Venus is significantly higher than the observed radio-brightness temperature for the small (at $\lambda = 10$ cm) optical thickness of the ionosphere in order to reconcile the results of the radio observations and the radar illumination data on Venus. The optical thickness of the ionosphere is proportional to the square of the wavelength and therefore, in the case being considered, the radio-brightness temperature at the 20- and 30-cm wavelengths should be considerably higher than at the 10-cm wavelength.

Curve 1 of Fig. 2 shows the variation of the brightness temperature T_{br} as a function of the optical thickness for $T_{\text{surface}} = 400°\text{K}$ and $T_e = 5000°\text{K}$. According to the experimental results, the brightness temperature of the 10-cm wavelength radiation falls in the range from 600 – 700°K. The interval $0.05 \leqslant \tau \leqslant 0.085$ of curve 1 of Fig. 2 corresponds to this range of temperatures. As indicated previously, such a value of the optical thickness of the ionosphere τ_{10} may under certain definite assumptions be reconciled with the radar observational data. For the 20-cm wavelength, the optical thickness will be four times as large: $0.20 \leq \tau_{20} \leq 0.34$, and the brightness temperature will correspondingly fall in the range $1240°K \leq T_{br} \leq 1760°K$. For $\lambda = 30$ cm, the corresponding values are $0.45 \leq \tau_{30} \leq 0.765$ and $2080°K \leq T_{br} \leq 2870°K$. Such a large increase of temperature with wavelength could not remain unnoticed. However, experiments (Ref. 47) have not disclosed any noticeable rise in temperature of the 20-cm radiation in comparison with the 10-cm radiation. Is it possible that the variation of T_{br} with wavelength follows some other pattern?

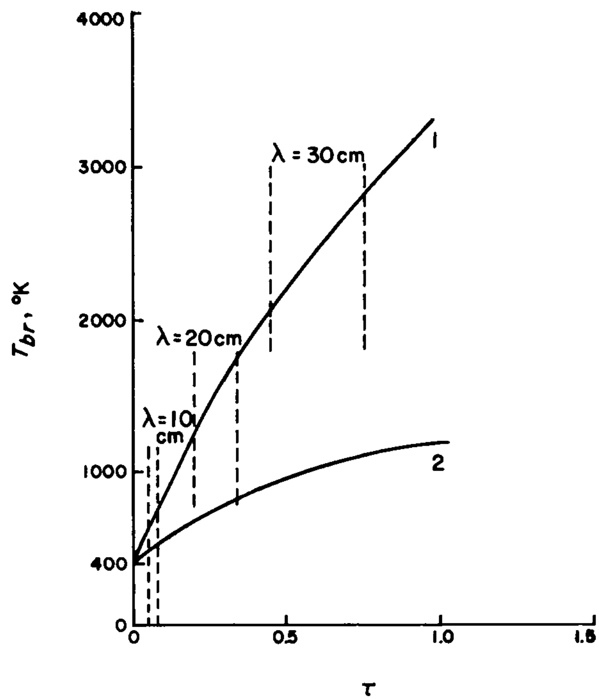

Fig. 2.

It has been mentioned earlier that at altitudes of 150 – 250 km in the Earth's ionosphere, the electron temperature is much higher than the temperature of the neutral atmosphere and reaches 2800°K (Ref. 41). At the same time, according to theoretical and experimental data (Ref. 48), in the upper portion of the F layer there is thermal equilibrium between the electrons and the neutral particles and the temperature of the ionosphere amounts to about 1000°K at night and 1600 – 1800°K in the daytime. This indicates that there is a colder layer in the Earth's atmosphere above the layer having the high electron temperature.

Assume that the same situation holds on Venus. Assume that there are two layers in the ionosphere of Venus: a lower layer with the optical thickness τ_1 and temperature T_1 and an upper cooler layer with optical thickness τ_2 and temperature T_2. Curve 2 of Fig. 2 presents the variation of T_{br} with τ for $T_{surface} = 400$, $T_1 = 5000$, $T_2 = 600°K$, $\tau_2 = 2\tau_1$. We notice that curve 2 is considerably flatter in comparison with curve 1, and, in the interval of interest to us, does not rise above 1200°. Thus, if in the ionosphere of Venus the temperature above a certain level decreases with height, then the variation of the radiation temperature with τ should be significantly weaker than for the case with a uniform electron temperature at all altitudes.

6. Figure 3 presents the available data on the radio-frequency radiation of Venus. The vertical lines indicate the accuracy of the corresponding experimental data and the solid lines represent the

theoretical radiation spectrum obtained on the assumption that (1) an ionosphere is responsible for the radio-frequency radiation of the planet at wavelengths above 3 cm, and that (2) the ionosphere consists of two layers with temperatures of 5000 and 600°K, respectively, with the optical thickness of the upper layer twice that of the lower layer and with $\int n^2\,dz = 10^{25}\ \mathrm{cm}^{-5}$. The two curves correspond to two different values of T_{br} at the 10-cm wavelength.

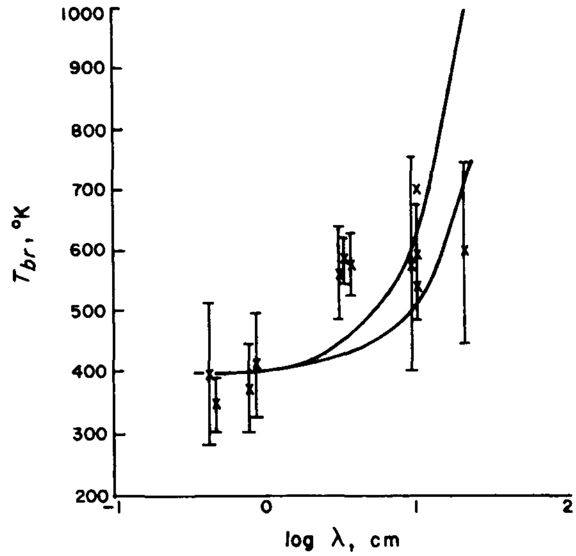

Fig. 3.

As seen from the plot, the theoretical temperatures differ somewhat from the experimental data for the 3- and 21-cm wavelengths. This difference, in our opinion, is not such a categorical difference that it would be necessary to discard entirely the model being considered or to give a negative answer to the question of the possibility of the ionospheric interpretation of the radio observations of Venus. It is necessary to keep in mind that at the 3.15-cm wavelength, a temperature of the order of 370°K has been obtained by extrapolation to the inferior conjunction (Ref. 11) while the measurement at the 21-cm wavelength is still a single isolated measurement of low accuracy. At the same time, it is necessary to note that the curves presented in Fig. 3 are the best approximation to the experimental data possible within the framework of the hypothesis under consideration. Analysis shows that there is no combination of optical thicknesses and temperatures of the two layers which can give a flatter shape to the curves of Fig. 3 if we start from the assumption that for the 10-cm wavelength we must have $\tau < 0.1$ and $T_{br} > 500$°K.

The following conclusions may be drawn from this analysis:

1. If in the ionosphere of Venus, in contrast with the situation in the ionosphere of the Earth, the radiative recombination of the atomic ions is the primary recombinational process, then the equilibrium concentrations of electrons in the Venus ionosphere may reach quite high values ($\int n_e^2\,dz = 10^{25}\ \mathrm{cm}^{-5}$).

2. Data on the natural radio-frequency radiation of Venus can be reconciled with the radar illumination data for the 10-, 40-, and 70-cm wavelengths if the 70-cm radiation is reflected from the ionospheric layer, the 40-cm radiation is wholly reflected from the surface and is absorbed in the ionosphere, while the 10-cm radiation is partially absorbed during reflection from the surface of the planet.

3. For the given value of $\int n_e^2 dz = 10^{25}$ cm^{-5}, the maximum concentration of electrons in the ionosphere of Venus may reach the value of $2 \cdot 10^9$ cm^{-3}, which is necessary for the reflection of the 70-cm wavelength only under the condition that the height of the uniform atmosphere near the peak electron concentration is no greater than 7 km.

4. If we try to explain the high temperature of the natural radiation of Venus at the 10-cm wavelength by the "heating" in the ionosphere of the radiation from the planet's surface, then, for the radiation with wavelengths of 20 and 30 cm, high temperatures of the order of 2000°K are obtained which are not actually observed. Such a sharp rise in the radiation brightness temperature might not be observed if there is a cooler layer in the ionosphere of Venus, with lower electron temperature above the layer having the high electron temperature.

Thus, at the present time, there are no experimental data which categorically refute the ionosphere hypothesis as a possible explanation for the radio-frequency radiation of Venus. However, to obtain fuller agreement of the theoretical distribution of temperature with the experimental data, we may consider several other possibilities associated with the ionosphere hypothesis, *e.g.*, the presence of ionospheric holes. The second part of the present investigation will be devoted to this question.

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